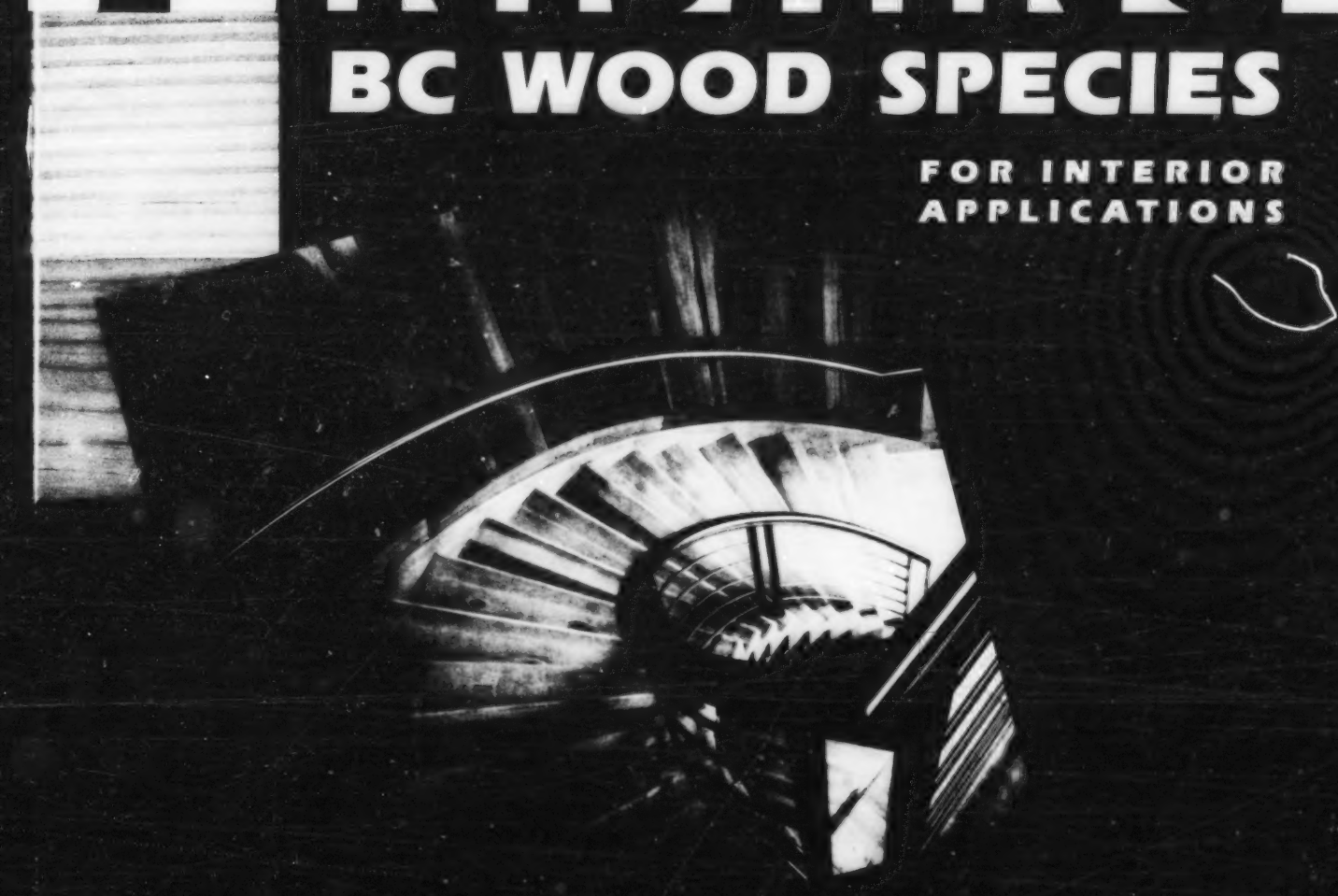
SPECIAL PUBLICATION SP-44

FINISHING BC WOOD SPECIES

FOR INTERIOR APPLICATIONS



Kevin Groves & Derek Williams

Forintek Canada Corp. *is Canada's wood products research institute providing the Canadian wood products industry and governments with services in research and development and technology transfer.*

Forintek's mission is to be the leading force in the technological advancement of the Canadian wood products industry, through the creation and implementation of innovative concepts, processes, products and education programs.

Forintek Canada Corp. *est l'institut de recherche sur les produits du bois du Canada. Forintek offre à l'industrie canadienne des produits du bois et aux gouvernements des services de recherche, de développement et de transfert technologique.*

Forintek a comme mission d'être le chef de file du progrès technologique de l'industrie canadienne des produits du bois par la création et la mise en oeuvre de concepts, procédés, produits et programmes de formation innovateurs.

© 2001, Forintek Canada Corp.

All rights reserved

No part of this published Work may be reproduced, published, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, whether or not in translated form, without the prior written permission of Forintek, except that members of Forintek in good standing shall be permitted to reproduce all or part of this Work for their own use but not for resale, rental or otherwise for profit, and only if Forintek is identified in a prominent location as the source of the publication or portion thereof, and only so long as such members remain in good standing.

This published Work is designed to provide accurate, authoritative information but it is not intended to provide professional advice. If such advice is sought then services of an appropriate professional should be retained for this purpose.

Acknowledgement

Funding for this research and/or extension project was provided by Forest Renewal BC. Funding assistance by Forest Renewal BC does not imply endorsement of any statements or information contained herein.

March 2001
Special Publication SP-44
ISSN # 0824-2119

Western Division/Division de l'Ouest
2665 East Mall
Vancouver, B.C. V6T 1W5
Tel/Tél: (604) 224-3221
FAX/Télécopieur: (604) 222-5690

Eastern Division/Division de l'Est
319, rue Franquet
Sainte-Foy, Québec G1P 4R4
Tel/Tél: (418) 659-2647
FAX/Télécopieur: (418) 659-2922

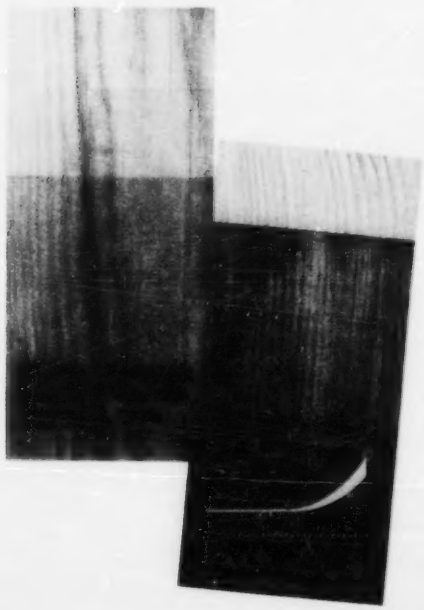
Internet: http://www.forintek.ca

101-06831/

FINISHING BC WOOD SPECIES FOR INTERIOR APPLICATIONS

Kevin Groves & Derek Williams

SPECIAL PUBLICATION SP-44



Acknowledgements

The authors wish to acknowledge Dave Lick, chief instructor at BCIT's Painting and Decorating Trades Department for his assistance in performing the furniture finishing test and evaluations. Special thanks are given to Brian Jung, a student from the Centre for Advanced Wood Processing at UBC, for his assistance and hard work in completing this project. We also wish to thank the Western Red Cedar Lumber Association and the Council of Forest Industries for providing many of the images of end-use wood products shown in this report. Finally, we thank our colleagues for reviewing the manuscript and for their many useful suggestions.

Abstract

This publication reports on a study carried out by Forintek Canada Corp. which examined the finishing properties of BC wood species and a number of competitive wood species from around the world. Some of the foreign wood species are well known and considered to be benchmark species. The procedures followed were standard tests for finish adherence as published by the American Society for Testing and Materials. The finishing tests determined the adhesion of a number of commonly used coatings for interior and exterior applications. A range of furniture-type finishes were applied to subjectively determine the appearance attributes of each species.

A number of BC wood species performed well with respect to known benchmark wood species. This information can be used to raise awareness of their potential.

Table of Contents

ACKNOWLEDGEMENTS ii

ABSTRACT ii

INTRODUCTION 4

ABUNDANCE OF BC WOODS 6

WOOD CHARACTERISTICS IMPORTANT TO FINISHING 6

The Wood's Natural (Pre-Finish) Appearance 6

Changing over to Second-growth Fibre 7

FINISH EVALUATION TESTS 8

FURNITURE FINISH APPEARANCE 8

Three-Step Production Finish System 8

Description of Finishes Used 8

Stains 8

Sealers 9

Top Coats 9

Finishing "Step Panel" Samples 9

Finish Application and Surface Preparation of Step Panels 10

Step Panel Evaluation and Results 10

Comparative Furniture Finish Evaluations 15

Old-growth, Second-growth and Interior Douglas-fir 15

Interior Douglas-fir and Western Larch 15

Old-growth Western Hemlock and Amabilis Fir 15

Old-growth, Second-growth and Interior Western Hemlock 16

White Spruce, Lodgepole Pine and Subalpine Fir 16

Domestic versus Imported Pines 17

Domestic versus Imported Spruces 18

Broadleaf Maple, Western White Birch and Red Alder 18

Wax Finishes 19

Equipment 19

Procedure 19

Wax Finish Results 20

FINISH ADHESION 20

Test Methods 20

Equipment 20

Procedure 20

Adhesion Test Results 21

CONCLUSIONS 24

Finish Appearance 24

Adhesion Testing 24

RECOMMENDATIONS 24

REFERENCES 24

LIST OF TABLES

Table 1	Wood Species Studied	5
Table 2	BC Log Harvest (Billed in 1997/98)	6
Table 3	Heartwood and Sapwood Comparisons between Species	7
Table 4	Hard Wax Finishing Test Results	19
Table 5	Tape Test Grading Categories	22
Table 6	Tape Test Results	22
Table 7	Pull-Off Test Results	23

LIST OF FIGURES

Figure 1	Heartwood and Sapwood Location	7
Figure 2	Vertical Grain	7
Figure 3	Flat Grain	7
Figure 4	Stain Colours	8
Figure 5	Step Panel	9
Figure 6	Spray Application of Finish	9
Figure 7	Finishing Results of Individual Species	10
Figure 8	Selected Furniture Finish/Species Combinations	10
Figure 9	Comparison between Amabilis Fir and Old-Growth Western Hemlock with Clear Finish	15
Figure 10	Comparison between Old-growth, Second-growth and Interior Western Hemlock with Walnut Oil Stain	16
Figure 11	Western Hemlock Showing Dark Streak	16
Figure 12	Comparison between Lodgepole Pine, Interior White Spruce and Subalpine Fir with Light Oak Penetrating Stain	16
Figure 13	Comparison between Domestic versus Imported Pines with Clear Finish (No Stain)	17
Figure 14	Comparison of Imported versus Domestic Spruce with Light Oak Pentrating Stain	18
Figure 15	Comparison of Hardwoods with Light Oak Pentrating Stain	18
Figure 16	Selected Wax Finish/Species Combinations	19
Figure 17	Scoring for Tape Test	21
Figure 18	Tape Pull-off Test	21
Figure 19	Pull-off Test Set-up	21
Figure 20	Plug for Pull-off Test	21

INTRODUCTION

As more wood processors consider the merits of adding value to their wood products, the need for practical information on British Columbia's substantial range of softwoods and, to a lesser extent, hardwoods becomes an important component of success. One of the best ways to add value to any wood product is to apply a coating to either beautify and/or protect the surface. Finished wood products tend to be retail-ready, a good indicator that virtually all the value that can be added is present in the product. Knowing whether or not a certain wood species can be successfully finished using standard industrial systems can provide the incentive for BC value-added wood producers to gain the maximum possible value.

Information available on the finishing properties of various wood species has usually been limited to how well paint adheres to the surface or whether it stains well or that varnish will work with the species. No information is given on what test methods were employed, the types of coating used, or even when the tests were conducted. At a time when there was an abundant supply of the better known species, lesser known wood species did not warrant much attention. However, much has changed in today's wood fibre supply; younger trees of the more commercially prominent wood species are being harvested, lesser known wood species are being increasingly used for value-added products, and there are more foreign wood species in competition with BC species in the domestic and foreign markets. Often more information is available on a broad range of the properties of competing species. At the same time there has been a huge improvement in coatings' technology that makes the older evaluations of wood finishing properties out of date and, at times, questionable.

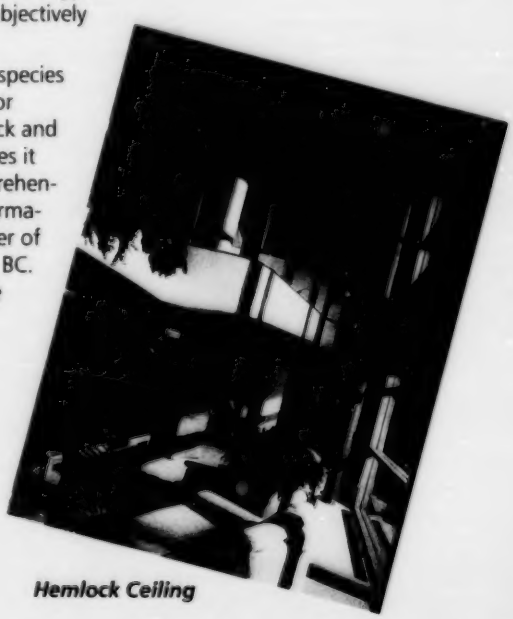
To fill the information gaps on the finishing properties of BC wood species and to see how these species compare with other commercially prominent softwood species from foreign sources, a series of finishing tests were undertaken.

The evaluation was conducted by determining coating adherence to a substrate and by subjectively evaluating the appearance attributes of each individual coating. Comparative evaluation of certain groupings of wood species was also conducted. The test procedure relied on coating industry tests to measure adhesion of a coating to a substrate using a broad range of commonly available wood finishes. The following ASTM test procedures were used: D 3359 *Test Method for Measuring Adhesion by Tape Tests* [1] and D 4541 *Test Method for Pull-Off Strength of Coatings Using Portable Adhesion-Tester* [2]. Appearance attributes were evaluated for indoor, furniture-type finishes including a conventional, production-type finishing system and wax coatings. The production-type finishing system covered a range of commercially available finishes including five types of stain, two sealers and three topcoats in various combinations. The evaluation of the appearance attributes followed no formal test procedure as none exist. In order to provide sound judgement, the opinion of an expert in the area of finish coatings was sought.

Pine Hutch

The wax finish evaluation also followed no formal test procedure other than the instructions provided by the wax finish manufacturer and the use of subjective evaluation to judge the results. A hard wax finish was used in the test. As with the furniture-type finishes, the results were subjectively evaluated.

This study covers 16 wood species with additional sub-types for Douglas-fir, western hemlock and western redcedar. This makes it possible to provide a comprehensive source of practical information on a substantial number of the wood species grown in BC. Table 1 gives a listing of the wood species studied.



Hemlock Ceiling

Table 1: Wood Species Studied

Common Name	Latin Name	BC Region/Country
[illegible]		
Amabilis fir	*Abies amabilis*	Pacific
Douglas-fir - old-growth	*Pseudotsuga menziesii*	Pacific
Douglas-fir - second-growth	*Pseudotsuga menziesii*	Pacific
Douglas-fir - Interior	*Pseudotsuga menziesii*	Interior Wetbelt
Lodgepole pine	*Pinus contorta*	Interior Plateau
Sitka spruce	*Picea sitchensis*	Pacific
Interior white spruce	*Picea glauca/engelmannii*	Rocky Mountain Trench
Subalpine fir	*Abies lasiocarpa*	Interior Subalpine
Western hemlock - old-growth	*Tsuga heterophylla*	Pacific
Western hemlock - second-growth	*Tsuga heterophylla*	Pacific
Western hemlock - Interior	*Tsuga heterophylla*	Interior Wetbelt
Western larch	*Larix occidentalis*	Rocky Mountain Trench
Western redcedar - old-growth	*Thuja plicata*	Pacific
Western redcedar - second-growth	*Thuja plicata*	Rocky Mountain Trench
Western white pine	*Pinus monticola*	Rocky Mountain Trench
Yellow cedar	*Chamaecyparis nootkatensis*	Pacific
[illegible]		
Bigleaf maple	*Acer macrophyllum*	Pacific
Red alder	*Alnus rubra*	Pacific
Trembling aspen	*Populus tremuloides*	Rocky Mountain Trench
Western white birch	*Betula papyrifera*	Rocky Mountain Trench
[illegible]		
Norway spruce	*Picea abies*	Sweden
Ponderosa pine	*Pinus ponderosa*	U.S.
Sitka spruce	*Picea sitchensis*	U.S.
Southern yellow pine	*Pinus palustris, P. elliottii, P. taeda, P. echinata*	U.S.

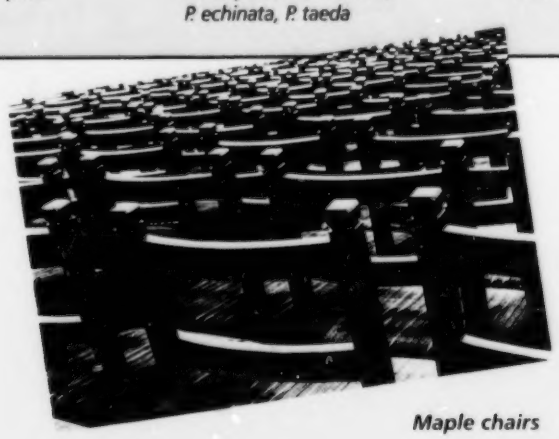
Maple chairs

Western Redcedar Soundboard

Table 1: Wood Species Studied

Common Name	*Latin Name*	*BC Region/Country*
Softwoods		
Amabilis fir	*Abies amabilis*	Pacific
Douglas-fir - old-growth	*Pseudeotsuga menziezii*	Pacific
Douglas-fir - second-growth	*Pseudeotsuga menziezii*	Pacific
Douglas-fir - interior	*Pseudeotsuga menziezii*	Interior Wetbelt
Lodgepole pine	*Pinus contorta*	Omineca-Peace
Sitka spruce	*Picea sitchensis*	Pacific
Interior white spruce	*Picea glauca/engelmannii*	Kootenay-Boundary
Subalpine fir	*Abies lasiocarpa*	Skeena-Bulkley
Western hemlock - old-growth	*Tsuga heterophylla*	Pacific
Western hemlock - second-growth	*Tsuga heterophylla*	Pacific
Western hemlock - interior	*Tsuga heterophylla*	Interior Wetbelt
Western larch	*Larix occidentalis*	Kootenay-Boundary
Western redcedar - coastal	*Thuja plicata*	Pacific
Western redcedar - interior	*Thuja plicata*	Kootenay-Boundary
Western white pine	*Pinus monticola*	Kootenay-Boundary
Yellow cedar	*Chamaecyparis nootkatensis*	Pacific
Hardwoods		
Broadleaf maple	*Acer macrophyllum*	Pacific
Red alder	*Alnus rubra*	Pacific
Trembling aspen	*Populus tremuloides*	Kootenay-Boundary
Western white birch	*Betula papyrifera*	Skeena-Bulkley
Imported Wood Species		
Norway spruce	*Picea abies*	Sweden
Ponderosa pine	*Pinus ponderosa*	U.S
Radiata pine	*Pinus radiata*	Chile
Southern yellow pine	*Pinus palustris, P. elliotti, P. echinata, P. taeda*	U.S.

Western Redcedar Soundboard



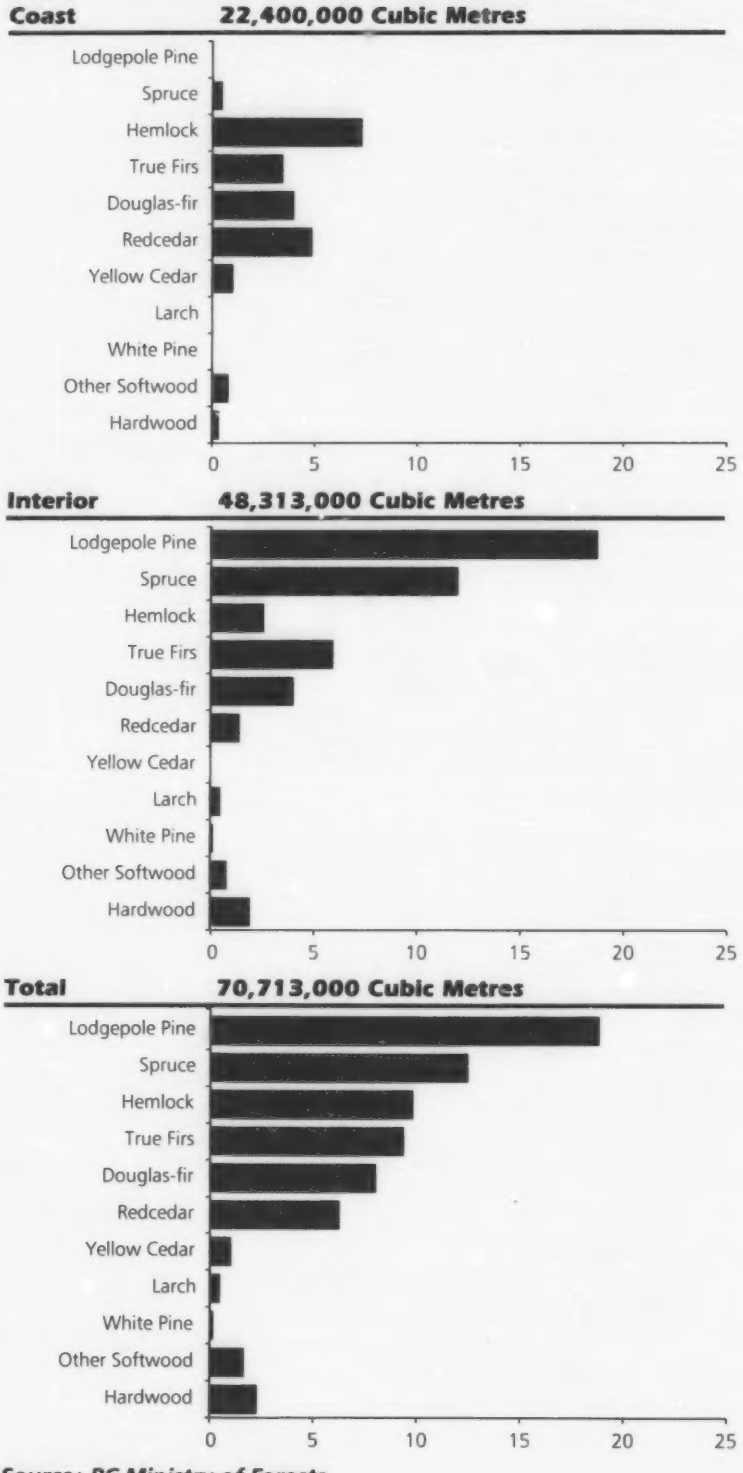
Maple chairs

Abundance of BC Woods

For finishing purposes, there are many species to choose from in BC. It is important to consider their relative abundance, availability and cost.

In 1997/1998, the BC log harvest was 70,713,000 cubic metres which were obtained from both private and public lands (Table 2). Roughly one-third of the 1997 BC log harvest came from coastal forests with hemlock leading the way in volume followed by western redcedar, Douglas-fir, true firs and yellow cedar. The true firs include mostly amabilis fir and subalpine fir. Close to two-thirds of the logs harvested were from the Interior. In this part of the province, lodgepole pine comprised the largest volume, followed by spruce, true firs, Douglas-fir and hemlock. Hardwood species in BC made up 3.3 per cent of the log harvest.

Table 2 BC Log Harvest (Billed in 1997/98)



Source: BC Ministry of Forests

Wood Characteristics Important to Finishing

There are several wood properties that are important to consider for finishing purposes. In this section, we address general aspects of the wood's natural appearance and the impact of the newer, second-growth fibre supply on finish appearance properties.

The Wood's Natural (Pre-Finish) Appearance

BC woods offer a wide range of appearance qualities that can be distinctive and carry through to the finished product. The most notable differences are found in the colouring and grain patterns.

Natural colouring can differ not only between species, but also within some species, mostly between the heartwood and sapwood (Figure 1). Relatively few of BC's species exhibit distinct differences between sapwood and heartwood while the majority show little colour difference (Table 3). Species that have noticeably darker heartwood are Douglas-fir, western redcedar

and western larch. In these cases, the heartwood tends to be reddish-brown.

After processing, the growth rings of a tree representing earlywood and latewood growth are displayed as the grain figure on the wood's surface. This can dramatically affect the appearance of the final finished product which can range from narrow, tightly spaced, vertical grain (Figure 2) to "cathedral" shaped flat grain (Figure 3). Douglas-fir is an example of a species with a distinct, conspicuous grain figure.

Latewood is generally darker in colour and denser than the earlywood. Because of this difference in density, stains can penetrate more into the earlywood and, in some cases, cause it to become darker than the latewood. This condition is called "grain reversal" and can be a useful technique to either highlight or even out grain patterns.

Vertical-grained wood is highly regarded for finishing purposes and is more common in old-growth trees compared to the newer second-growth resource. The best way to control flat and vertical grain content is to select the appropriate log cutting pattern. Most lumber in BC today is "plainsawn" which cuts tangentially to the growth rings and produces flat-grain lumber for the general purpose marketplace. To produce vertical grain, wood is "quartersawn" by cutting radially to the rings. This is less efficient in terms of wood recovery but is the best way to obtain vertical grain and is used primarily by producers of specialty wood products.

Changing over to Second-growth Fibre

The changing nature of today's forests is resulting in less availability of old-growth fibre, the resource most relied upon for higher, appearance grades of lumber for finishing purposes. Second- and even third-growth wood is being used to a greater extent today and this is expected to continue into the future. Changing over to this newer resource poses a challenge to the wood products industry because there are different appearance and structural properties to consider. Ultimately, these differences show up in the final product and need to meet with customer acceptance.

To better understand the impact on finishing performance it is important to know a few of the basic differences in the woods from these two resource types. First of all, lumber derived from old-growth is characterized by high percentages of clear (free from knots and other defects) grades, with very fine, uniform rings of annual growth. The larger old-growth logs

Figure 1

Heartwood and Sapwood Location (Sample shown is western redcedar with its distinctive dark-coloured heartwood.)

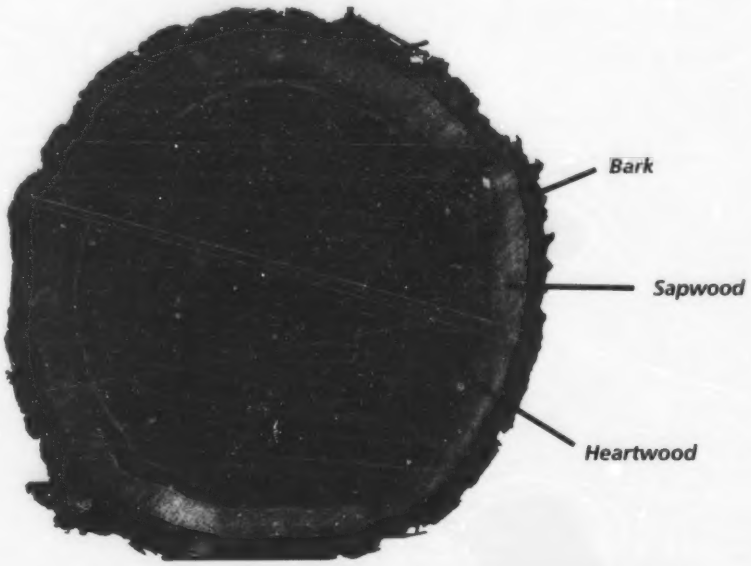


Table 3 Heartwood and Sapwood Comparisons between Species

Dark-coloured, distinct heartwood	Western redcedar	(reddish-brown)
	Western larch	(reddish-brown)
	Douglas-fir	(reddish-brown)
Light-coloured heartwood and little contrast between heartwood and sapwood	Western hemlock	Aspen
	Spruce	Maple
	White pine	Alder
	Lodgepole pine	Birch
	Yellow cedar	Cottonwood

Source: BC Ministry of Forests

Figure 2

Vertical Grain

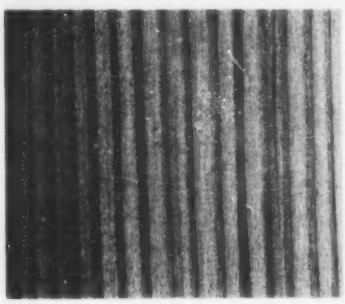


Figure 3

Flat Grain

and western larch. In these cases, the heartwood tends to be reddish-brown.

After processing, the growth rings of a tree representing earlywood and latewood growth are displayed as the grain figure on the wood's surface. This can dramatically affect the appearance of the final finished product which can range from narrow, tightly spaced, vertical grain (Figure 2) to "cathedral" shaped flat grain (Figure 3). Douglas-fir is an example of a species with a distinct, conspicuous grain figure.

Latewood is generally darker in colour and denser than the earlywood. Because of this difference in density, stains can penetrate more into the earlywood and, in some cases, cause it to become darker than the latewood. This condition is called "grain reversal" and can be a useful technique to either highlight or even out grain patterns.

Vertical-grained wood is highly regarded for finishing purposes and is more common in old-growth trees compared to the newer second-growth resource. The best way to control flat and vertical grain content is to select the appropriate log cutting pattern. Most lumber in BC today is "plainsawn" which cuts tangentially to the growth rings and produces flat-grain lumber for the general purpose marketplace. To produce vertical grain, wood is "quartersawn" by cutting radially to the rings. This is less efficient in terms of wood recovery but is the best way to obtain vertical grain and is used primarily by producers of specialty wood products.

Changing over to Second-growth Fibre

The changing nature of today's forests is resulting in less availability of old-growth fibre, the resource most relied upon for higher, appearance grades of lumber for finishing purposes. Second- and even third-growth wood is being used to a greater extent today and this is expected to continue into the future. Changing over to this newer resource poses a challenge to the wood products industry because there are different appearance and structural properties to consider. Ultimately, these differences show up in the final product and need to meet with customer acceptance.

To better understand the impact on finishing performance it is important to know a few of the basic differences in the woods from these two resource types. First of all, lumber derived from old-growth is characterized by high percentages of clear (free from knots and other defects) grades, with very fine, uniform rings of annual growth. The larger old-growth logs

Figure 1

Heartwood and Sapwood Location (Sample shown is western redcedar with its distinctive dark-coloured heartwood.)

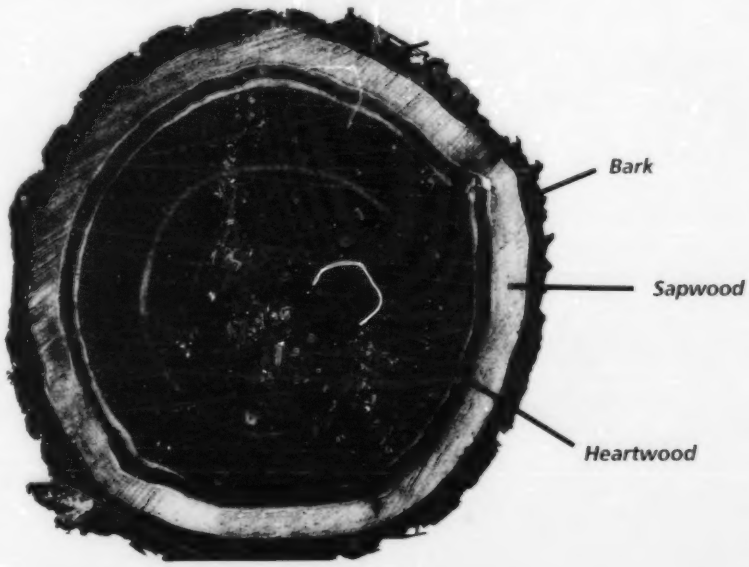


Table 3 Heartwood and Sapwood Comparisons between Species

Dark-coloured, distinct heartwood	Western redcedar Western larch Douglas-fir	(reddish-brown) (reddish-brown) (reddish-brown)
Light-coloured heartwood and little contrast between heartwood and sapwood	Western hemlock Spruce White pine Lodgepole pine Yellow cedar	Aspen Maple Alder Birch Cottonwood

Source: BC Ministry of Forests

Figure 2

Vertical Grain

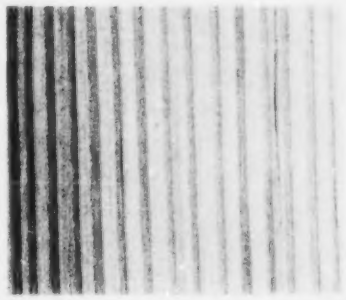


Figure 3

Flat Grain

yield relatively high percentages of heartwood and lumber with vertical grain. By contrast, smaller diameter, more rapidly grown, second-growth trees yield higher percentages of flat-grained lumber containing knots and other characteristics including sapwood. Douglas-fir and western hemlock are two well known BC species that were assessed in this study to further examine the differences between old- and second-growth.

Finish Evaluation Tests

The finishing tests determined the applicability of finishing any of the wood types when a typical paint-type coating, a furniture-type coating or a wax coating was applied. One of the most important tests for a finish is how well it will adhere to a surface. Hence the first test was to determine how well a number of finishes, most of which were paint-type finishes, adhered to each of the wood species. This was followed by a subjective evaluation of the appearance of the furniture-type coatings. The furniture finish types included a three-step, production-type finish system to enhance the wood grain and to offer it protection, and a wax-type finish which enhances the wood grain, but offers the least amount of protection.

Furniture Finish Appearance

The appearance of the final finished product is arguably the most important attribute to consider when deciding which finish to use for a particular wood species. After all, many consumers tend to "judge a book by its cover." It is also an understatement that a well-chosen and properly applied finish for a particular wood substrate adds value to the final product. Knowledge about how various finishes appear on different wood substrates is a powerful tool that manufacturers can use to help them determine how they portray their product. The finish can be used to accentuate, hide or even out particular wood surface features according to the customers' tastes. The finish can also be used to help "cheaper" woods imitate exotic, more valuable types.

In this section, we examine two different types of finish including a conventional, three-step, production-type finishing system and a specialty-type wax finish system which is more commonly used in Europe.

Three-Step Production Finish System

The "three-step" finishing system investigated in this study involved the application of a stain, sealer and top coat. These are easy-to-apply finishes that are applicable for both amateur and production factory finishers. They are "off-the-shelf" and are representative of what is available from finishing suppliers. They range from traditional solvent-based treatments to the newer, more environmentally-friendly water-borne treatments. In this study, the furniture finish tests involved the use of five stains, two sealers and three top coats used in various combinations for each of the BC species. Finished samples were assessed visually with the assistance of a finishing expert and the results are provided later in this chapter. A section is included which discusses many important comparisons between different domestic and foreign species.

Description of Finishes Used

Stains

Stains can beautify the wood by adding colour and richness. They can also either emphasize or disguise specific features of the wood including grain pattern and colour variation. They can make less attractive, cheap woods resemble those that are more expensive and highly regarded.

The following stains plus a clear finish (no stain) were used in this study:

1) *Light Oak Penetrating Stain* *
2) *Walnut Oil Stain* *
3) *Green Toner – (Alcohol Based)* *
4) *Mahogany Penetrating Stain* *
5) *Dark Walnut – Analine Dye Water Stain*

These stains are shown on interior Douglas-fir in Figure 4.

Note - *The symbol * indicates a solvent-based coating whereas no symbol indicates a water-borne coating.*

Alcohol and penetrating stains are the fastest drying followed by oil- and water-borne stains. The latter is dependent on relative humidity conditions (the higher the humidity the longer the drying time).

Sealers

The purpose of the sealer is to stop-up or seal the pores of the wood and lock or consolidate the wood surface fibres in preparation for sanding and subsequent topcoat application. In some cases, the sealer finish can feel rough due to the raised fibres and requires sanding. Specially prepared sanding sealers are formulated to enable easier, faster sanding of the surface which in turn speeds up production.

The sealers used were:

1) *Lacquer Sanding Sealer* *

2) *Pre-Catalyzed Alkyd/Nitrocellulose Sealer* *

The lacquer sanding sealer is economical and fast drying while the pre-catalyzed alkyd/ nitrocellulose sealer is a higher quality and more expensive fast drying product.

Top Coats

Top coats increase the thickness of the film and can add decorative colour, depth and various degrees of smoothness to the final product. Top coats also function as the protective layer against water incursion, dirt and abrasion.

The clear top coats used were:

1) *Semi-Gloss Lacquer* *

2) *Satin – Acrylic Water Based*

3) *35 degree – Pre-Catalyzed Alkyd/ Nitrocellulose* *

The semi-gloss sealer is a fast drying, low build clear coating with medium sheen. The satin-acrylic water-borne dries more slowly than solvent topcoats and is dependent on relative humidity. The 35 degree - pre-catalyzed alkyd/ nitrocellulose top coat dries fastest with low sheen and has a good build.

Finishing "Step Panel" Samples

Finish-system sample pieces in the furniture industry are called step panels where small 5 cm sections across the width of a sample piece are masked off so that they will not be coated by the next layer of coating material (Figure 5). This way the colour build up of the finish can be seen from start to finish. To enable easy comparisons between finishes on different woods, all wood samples used in this study were prepared as step panels of convenient, compact size (10 x 60 x 2 cm).

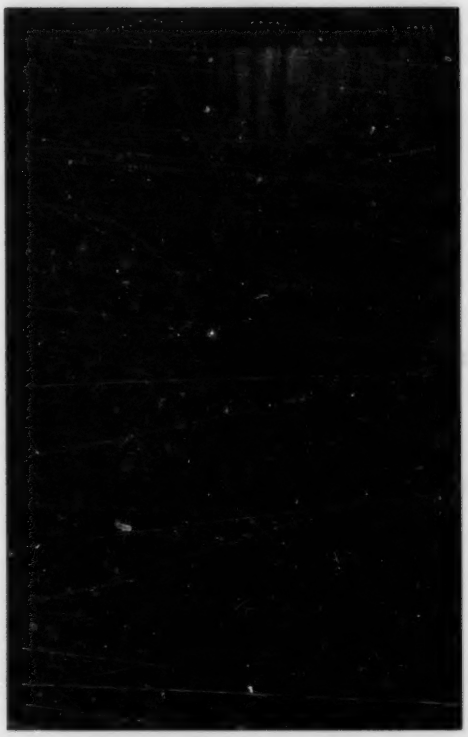


Figure 5
Step Panel

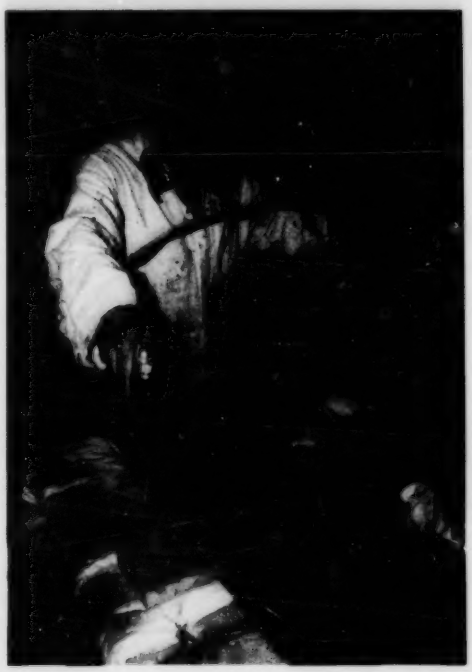


Figure 6
Spray Application of Finish

Finish Application and Surface Preparation of Step Panels

With each finish, the manufacturer's recommendations were followed to ensure proper surface preparation, application methods and drying intervals between finish steps. All finishes were applied by a hand-held HVLP (high volume, low pressure) air-spray system (Figure 6) because it is more efficient than brushing or rubbing with rags. This method also enables the finish coats to be laid down very evenly in a short amount of time. Special care was taken to ensure that all surfaces were free of any debris at each step.

Prior to staining, all wood was checked for acceptable moisture content (< 15%) and then machine sanded with 150 grit paper to bring the surface to a desired level of smoothness and remove any machining marks. The stain coating was applied and then wiped with a cloth to remove excess. For the next step, the sealer was applied and, once dry, sanded with 180 grit aluminum oxide paper to smooth the surface. In the final step, the topcoats were then applied.

Step Panel Evaluation and Results

The finishing consultant, using his expertise, then evaluated each sample according to industry norms. The following four pages (Figure 7) show all species/stain combinations evaluated in this study along with expert comments and useful finishing tips. This helps illustrate not only the differences in appearance between species but also the differences between the various finishing stages from bare wood to the final product. Step panels shown below (Figure 8) highlight those species/finish combinations which worked especially well together to produce a high quality appearance.

For some species, the finishing consultant recommends a wash coat to even out the stain colour. A wash coat is a pre-stain treatment of the wood surface with a diluted sealer (typically 1 part sealer to 10 parts solvent). This helps prevent uneven absorption of stain causing discolouration.

Figure 7
Finishing Results of Individual Species

Figure 8 Selected Furniture Finish/Species Combinations

WOOD	Interior Douglas-fir	Western Hemlock - Second-growth	Lodgepole Pine
STAIN (SPRAYED THEN WIPED)	Walnut Oil Stain	Mahogany Penetrating Stain	Clear Finish
SEALER (ONE COAT)	Pre-Catalized Alkyd/ Nitrocellulose Sealer	Pre-Catalized Alkyd/ Nitrocellulose Sealer	Lacquer Sanding Sealer
CLEAR FINISH (TWO COATS)	Satin - Acrylic Water Based	Satin - Acrylic Water Based	Semi-gloss Lacquer

Finish Application and Surface Preparation of Step Panels

With each finish, the manufacturer's recommendations were followed to ensure proper surface preparation, application methods and drying intervals between finish steps. All finishes were applied by a hand-held HVLP (high volume, low pressure) air-spray system (Figure 6) because it is more efficient than brushing or rubbing with rags. This method also enables the finish coats to be laid down very evenly in a short amount of time. Special care was taken to ensure that all surfaces were free of any debris at each step.

Prior to staining, all wood was checked for acceptable moisture content (<15%) and then machine sanded with 150 grit paper to bring the surface to a desired level of smoothness and remove any machining marks. The stain coating was applied and then wiped with a cloth to remove excess. For the next step, the sealer was applied and, once dry, sanded with 180 grit aluminum oxide paper to smooth the surface. In the final step, the topcoats were then applied.

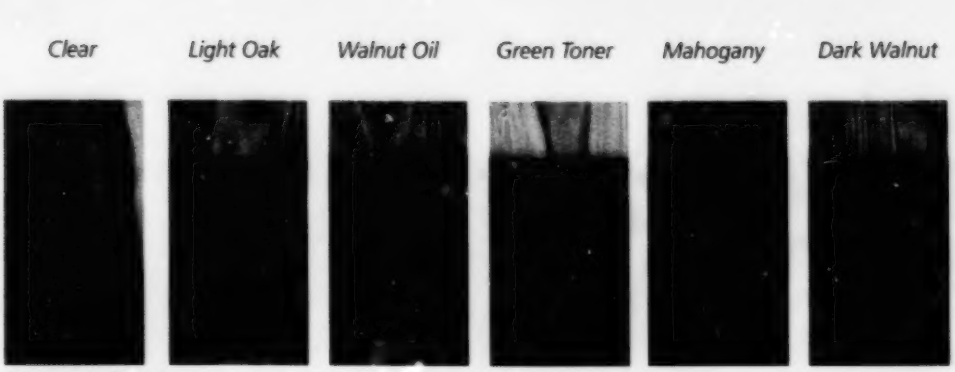
Step Panel Evaluation and Results

The finishing consultant, using his expertise, then evaluated each sample according to industry norms. The following four pages (Figure 7) show all species/stain combinations evaluated in this study along with expert comments and useful finishing tips. This helps illustrate not only the differences in appearance between species but also the differences between the various finishing stages from bare wood to the final product. Step panels shown below (Figure 8) highlight those species/finish combinations which worked especially well together to produce a high quality appearance.

For some species, the finishing consultant recommends a wash coat to even out the stain colour. A wash coat is a pre-stain treatment of the wood surface with a diluted sealer (typically 1 part sealer to 10 parts solvent). This helps prevent uneven absorption of stain causing discolouration.

Figure 7
Finishing Results of Individual Species

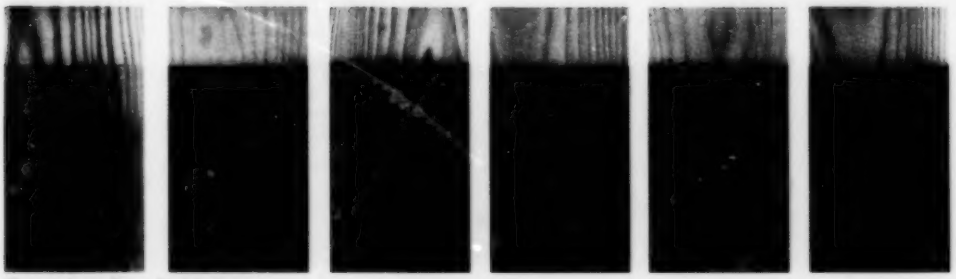
Figure 8 Selected Furniture Finish/Species Combinations



Western Larch

Western larch

Recommend multiple clear coats or a high build clear finish to achieve smooth texture. Wild grain is very visible when a dark stain is used.



Douglas-fir - Interior

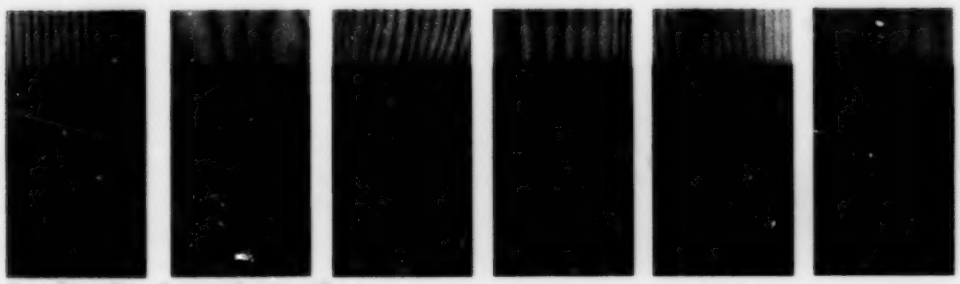
Douglas-fir - Interior

Stainability is average for light colours and poor for dark. Best finish with light stain followed by any of the three finish clear coats.

Douglas-fir - Old-growth

Douglas-fir - Old-growth

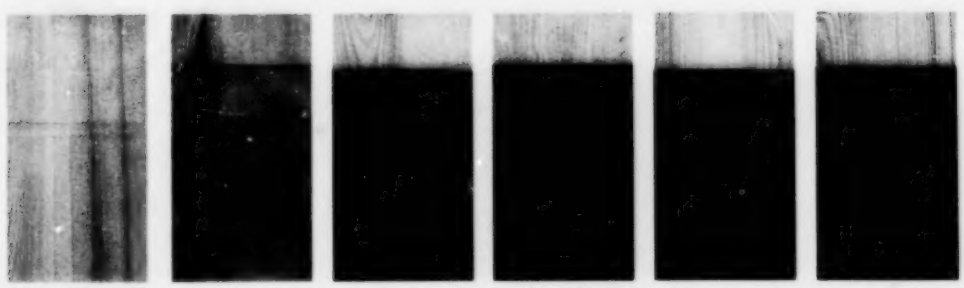
Smooth finish achieved. Grain becomes wild and pronounced with dark stain. A clear coating works the best.



Douglas-fir - Second-growth

Douglas-fir - Second-growth

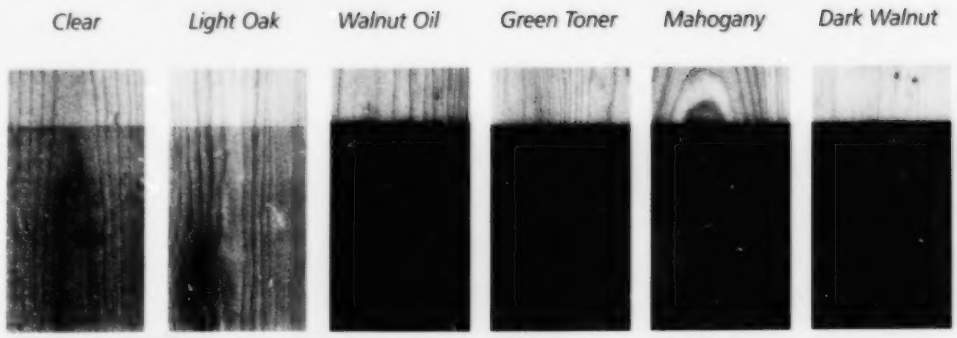
Stainability is average for light colours, poor for dark. Good results with light stain or clear finish followed by nitrocellulose alkyd clear sealer and finish.



Amabilis Fir

Amabilis fir - Old-growth

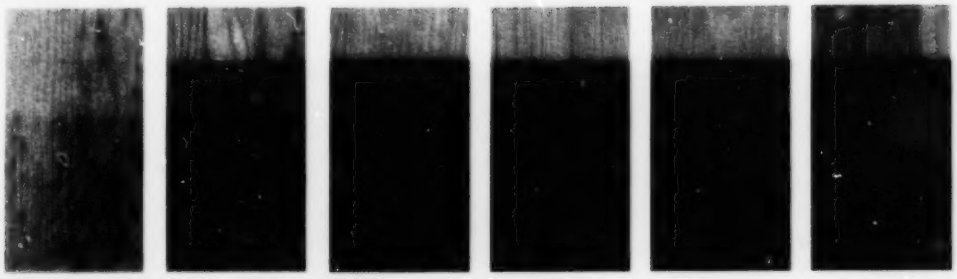
Wood is soft and produces a grainy appearance. Natural finish and light stains look the best. Dark stains appear blotchy. Multiple coats of clear or a clear coat with a high build is recommended.



Western Hemlock - Interior

Western hemlock - Interior

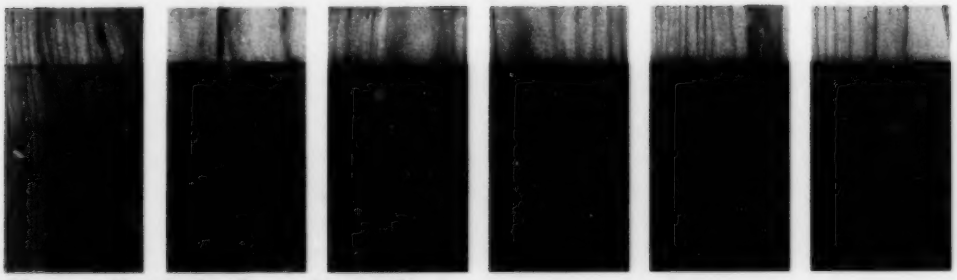
Excellent results with clear finish. Stainability is average with light colours working the best. Recommend clear nitrocellulose/ alkyd sealer and finish coat.



Western Hemlock - Old-growth

Western hemlock - Old-growth

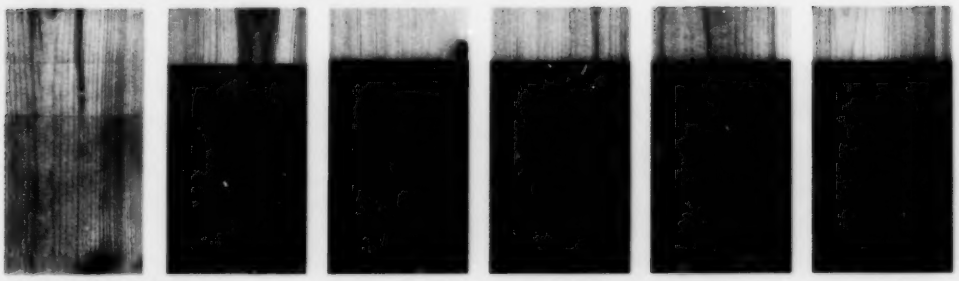
Smooth texture achieved. Natural finish (clear coat) looks best. As stain gets darker, prominent, wild grain is visible. A wash coat would even out the colour.



Western Hemlock - Second-growth

Western hemlock - Second-growth

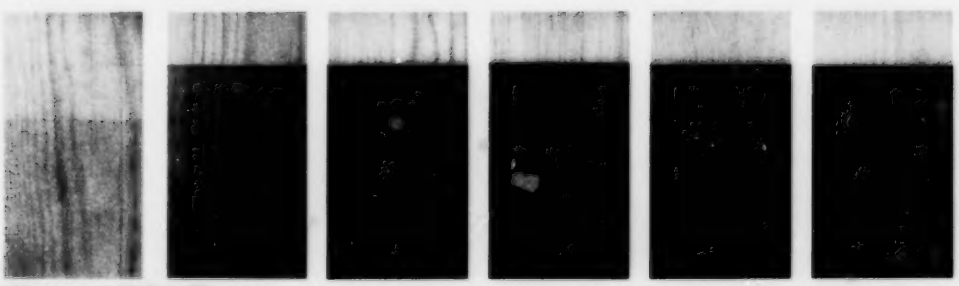
Excellent results with clear finish. Stainability is average for light colours, poor for dark. Best finish is with light stain or clear finish followed by nitrocellulose alkyd clear sealer and finish.



Lodgepole Pine

Lodgepole pine

Light stain and a natural finish work the best. Surface is smooth with only two topcoats. Dark stains produce wild grain. A wash coat would even out colour.

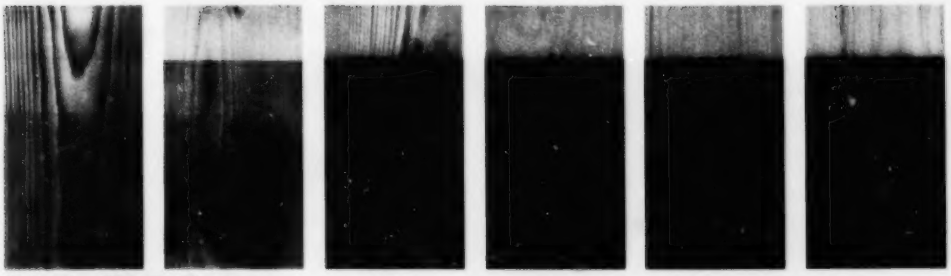


Western White Pine

Western white pine

Wood is soft and produces grainy appearance. Natural finish and light stains look best. Dark stains appear blotchy. Multiple coats of clear or a clear coat with a high build is recommended.

Clear | Light Oak | Walnut Oil | Green Toner | Mahogany | Dark Walnut



Interior White Spruce

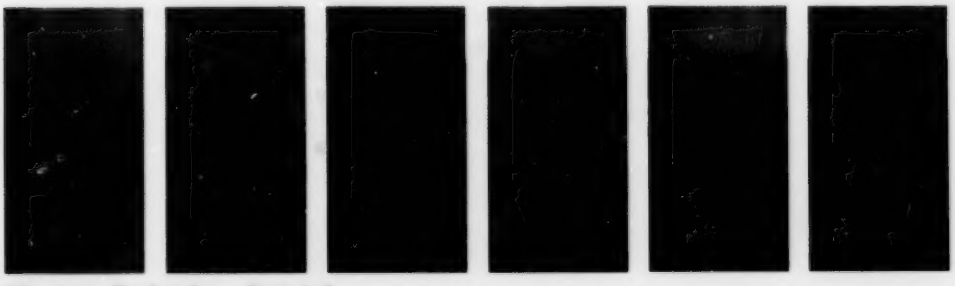
Interior white spruce

A smooth finish was achieved. A natural finish (clear coat) or a light stain looks the best.

Sitka Spruce

Sitka spruce

Smooth finish achieved. Light stains work well but dark stains magnify the uneven colours produced by different textures in wood. A wash coat would even out the colour.



Western Redcedar - Coastal

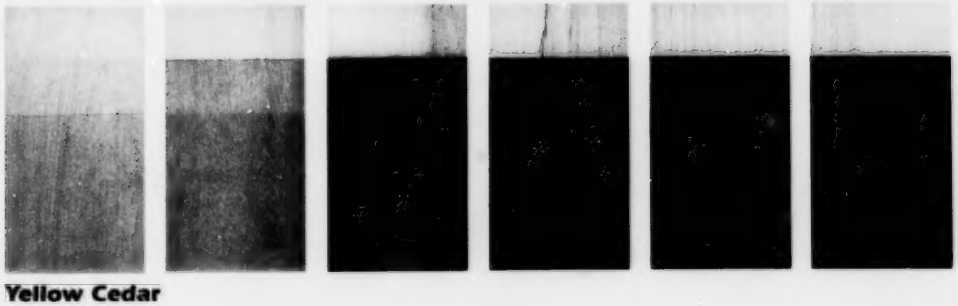
Western redcedar - coastal

Very smooth texture achieved. Very soft wood that loses some grain design as stain becomes darker. Clear coats with little difficulty. A high build clear works best.

Western Redcedar - Interior

Western redcedar - interior

Excellent results with clear finish. Stainability good to average with some wild grain. Good smoothness with some natural texture hard to hide. Recommend clear finish, nitrocellulose/ alkyd sealer and finish system.



Yellow Cedar

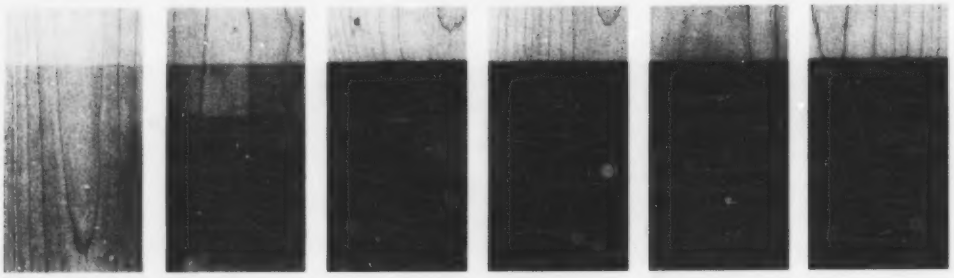
Yellow cedar

Natural finish looks best. As stain gets darker, uneven colour is pronounced. Reasonably smooth results with only two topcoats. A wash coat would even out colour differences.

Subalpine Fir

Subalpine fir

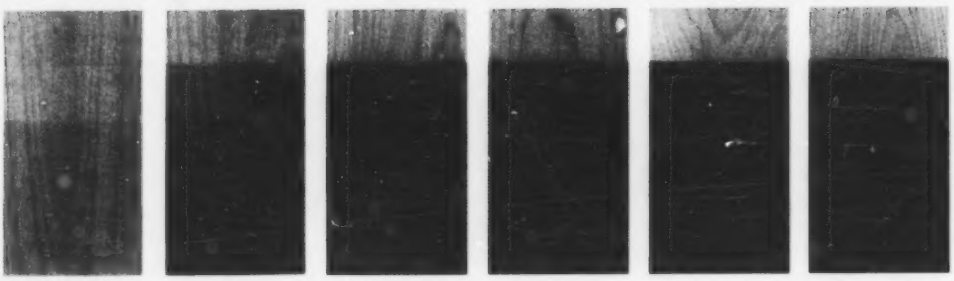
Smooth finish with little texture. Dark stains produce prominent wild grain. Light coloured stains with low penetration power will produce a more even colour.



Broadleaf Maple

Broadleaf maple

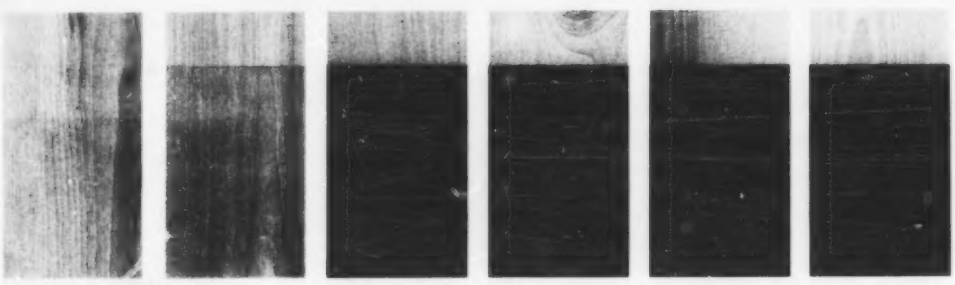
Excellent results with clear finish. Good to excellent stainability especially with light colours. Recommend light stain or clear finish followed by nitrocellulose/ alkyd clear, sealer and finish.



Red Alder

Red alder

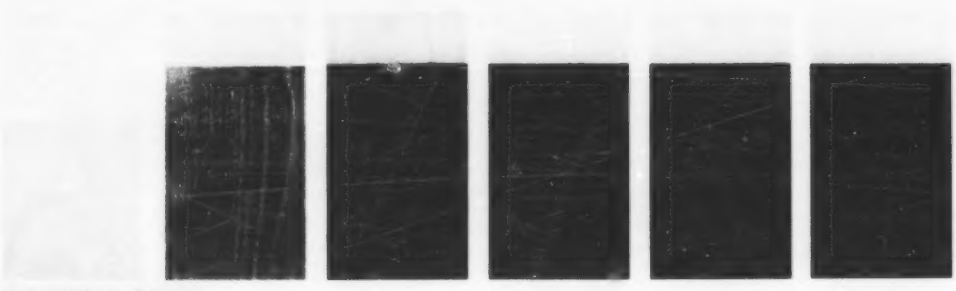
Attractive natural colour. Light stain works well. Blotchy when dark stain used. Smooth finish achieved.



Western White Birch

Western white birch

Very smooth finish. Natural finish is the best. Typical uneven colour becomes apparent as stain becomes darker. Could have a pigmented finish applied very easily with good results.



Trembling Aspen

Trembling aspen

Finishes well. Blotches do appear with darker stains. Light to medium stains work best.

Comparative Furniture Finish Evaluations

The following comparisons examine the differences between a number of wood species, based on the evaluation of samples produced for this study. These species are either marketed together or are variants of the same species or all belong to the same species but are from different growing areas or different age classes. Comparisons are also made between domestic and foreign species within the pine and spruce groups.

The comments made concerning the various finish systems are based on the colour produced by the stain, its evenness across the sample, the presence of blotchiness and on the general attractiveness of the finished wood sample.

Old-growth, Second-growth and Interior Douglas-fir

Traditionally, Douglas-fir has been mainly used for structural purposes but is now gaining in popularity for finishing applications with its distinctive natural colouring and grain structure. In this section, a comparison is made of the finishing properties between the better known coastal, old-growth fibre and its second-growth and interior grown variants.

Finished samples showed obvious differences in the grain figure. The second-growth and interior variants were comprised mainly of mixed grain (vertical-grain on the sides and flat-grain in the middle) while the old-growth samples were mostly straight, close-spaced, vertical grain. The mixed grain samples were appealing, especially with the interior variant, while the old-growth edge-grain was less attractive with some blotchiness observed with the darker stains. In addition, the old-growth samples with flat-grain had a "wild", unattractive appearance, somewhat like the flat-grain on rotary peeled plywood.

The same colouring was obtained for the three lots, therefore they could be intermixed if need be. All finishes worked well except the water-borne stain and darker stains on old-growth, edge-grain. In general, colour consistency was excellent when the mahogany and walnut oil stains were applied. These stains also highlighted the attractiveness of the grain figure of the interior and second-growth fibre.

Interior variant finishes very well

Interior Douglas-fir and Western Larch

These two species are often combined when marketing to the structural lumber market. Their colouring and grain figure are reasonably similar, and therefore they can be used in the same finished wood product. Lighter coloured stains gave the best results in this study. By comparison, the darker coloured walnut and dark walnut stains are not recommended due to the unattractive grain reversal they produced.

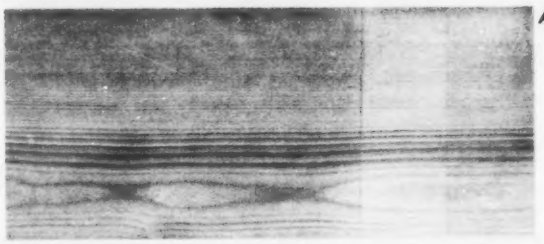
Similar colouring with light finishes gives best results

Old-growth Western Hemlock and Amabilis Fir

These two species, marketed together as "hem-fir", have a discernible difference in their colouring which is noticeable when a clear or light stain finish is applied (Figure 9). Mixing the lighter amabilis fir with the darker hemlock in the same product could be objectionable to high-end value-added wood product manufacturers.

Therefore, for lighter finishes, it would be advisable to separate these two species for use in finished wood products. Darker stains do have the ability to mask the colour difference but it was found that only the walnut oil gave good results. The dark walnut (water-borne) stain is not recommended because of its blotchy appearance on both species.

Staining required to even out differences in natural colour



Amabilis Fir

Old-growth Western Hemlock

Figure 9

Comparison between amabilis fir and old-growth western hemlock with clear finish

Figure 11
Western hemlock showing dark streak

Old-growth, Second-growth and Interior Western Hemlock

This comparison was made to see if there is any visual difference between old-growth western hemlock and its two variants. The interior and second-growth variants were mainly comprised of mixed grain while the old-growth was mostly edge grain with some flat grain samples. When finished, the mixed grain samples were more visually appealing compared to the tighter edge grain samples of the old-growth (Figure 10). In addition the black streaks that are sometimes present in the old-growth hemlock were not evident in the interior and were present in only the occasional second-growth sample (Figure 11). These streaks, permitted by the grading rules, can be objectionable as they can distract from the overall appearance of the finished wood.

The best finishing results were obtained with the clear, light oak and walnut oil stains applied to the second-growth and interior samples. Blotchiness was more of a problem with the old-growth samples and was especially evident for all three wood types when mahogany, dark walnut and green toner stains were used.

[redacted]

Old-growth Western Hemlock

Interior Western Hemlock

Second-growth Western Hemlock

Figure 10
Comparison between Old-growth, Second-growth and Interior Western Hemlock with Walnut Oil Stain

White Spruce, Lodgepole Pine and Subalpine Fir

Lodgepole Pine ***Interior White Spruce*** ***Subalpine Fir***

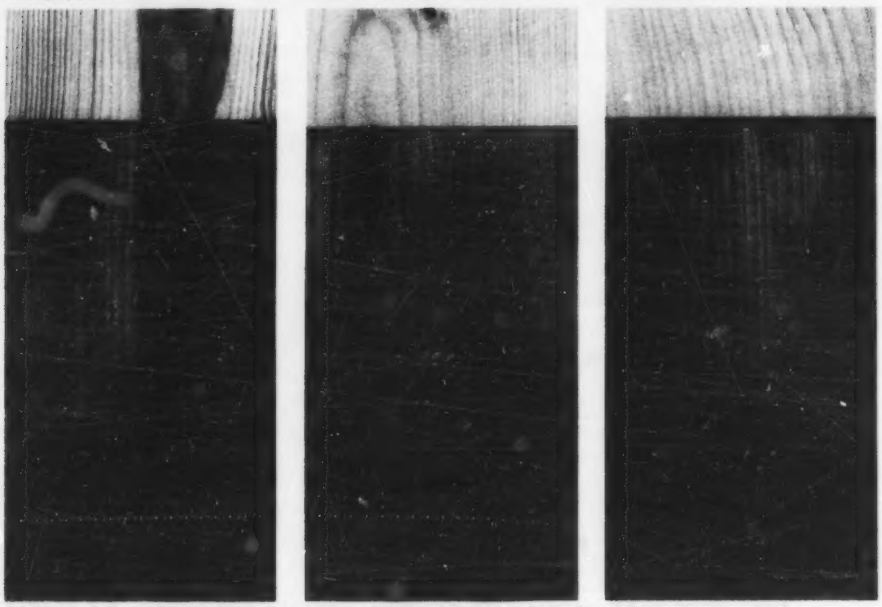


Figure 12 ***Comparison between Lodgepole Pine, Interior White Spruce and Subalpine Fir with Light Oak Penetrating Stain***

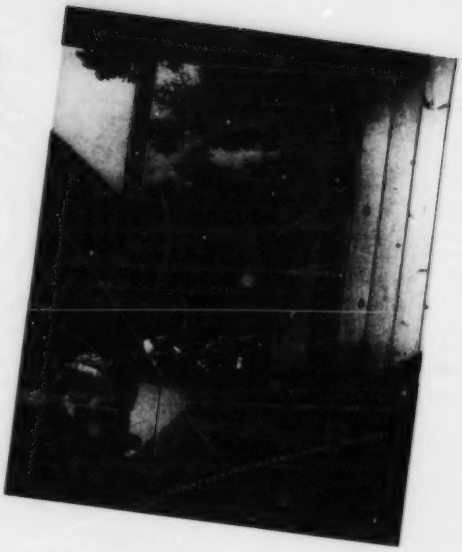
The finish performances of these species are compared because they are commonly grouped together and marketed as SPF for use as structural lumber as well as other uses. Their colouring is reasonably similar which makes it possible for them to be used in the same finished wood product provided that light coloured stains are used (Figure 12). All the stains produced good results except for the water-borne stain, which produced a high degree of blotchiness and grain reversal. The pine and spruce samples were more visually appealing with their grain figure when compared to fine vertical-grain of subalpine fir in the samples.

[redacted]

Domestic versus Imported Pines

This comparison evaluated a selection of western Canadian pines along with some of the most highly regarded benchmark pines such as ponderosa pine and southern yellow pine from the US. Lodgepole pine and western white pine had tight knots present whereas the other pines were all clear samples. With the exception of southern yellow pine, with its characteristic yellow colouring and contrast between early and latewood, all the other pines had the same shade. Radiata pine was all flat-grain with very wide growth rings that did not add much to its general appearance. Ponderosa pine is a highly regarded wood species with its attractive figure in the grain and no knots; western white pine came a close second to ponderosa pine in this regard.

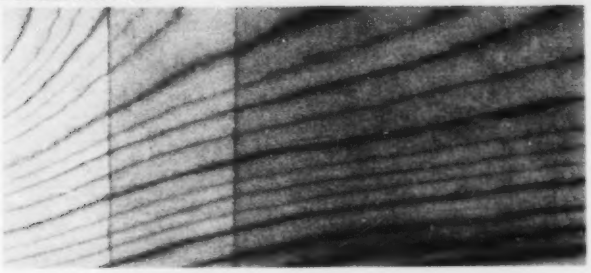
The pines from BC did as well as the benchmark pines and in some cases exceeded them in appearance when finished. The fast-grown radiata pine not only looked unappealing with its wide growth rings but it also performed the poorest with problems encountered with blotchiness and colour inconsistency. Both the lighter stains and clear finishes performed best with the pines (Figure 13). The water-based stain did not work well except on ponderosa pine.



IMPORTED

Radiata Pine

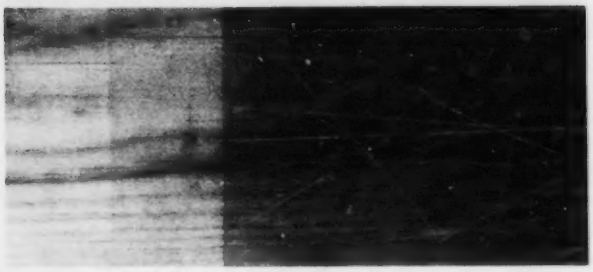
Ponderosa Pine



Southern Yellow Pine

DOMESTIC

Western White Pine



Lodgepole Pine

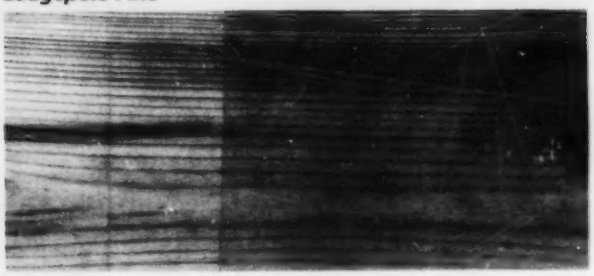
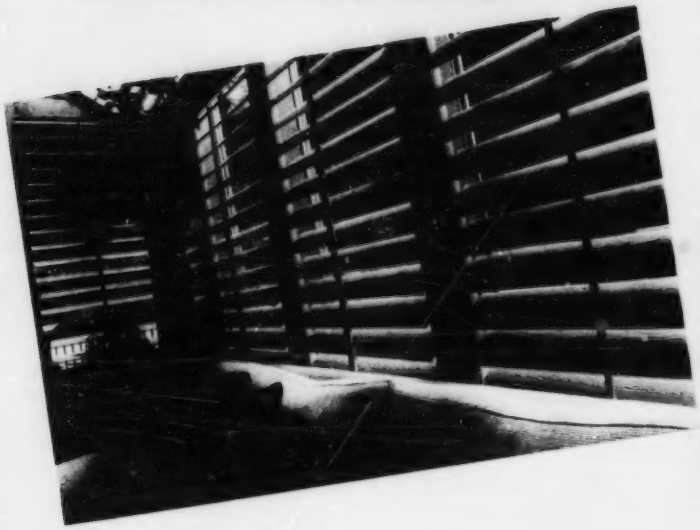


Figure 13

Comparison between Domestic versus Imported Pines with Clear Finish (No Stain)

Domestic versus Imported Spruces

Finished interior white spruce and Norway spruce have almost identical colouring and could easily be substituted for each other (Figure 14). The white spruce was just slightly better than the Norway spruce. The sitka spruce samples, most of which were vertical-grain, had a slightly darker colouring than the other two spruces though it is not likely that these species would be found in the same product. The lighter and medium tone stains performed well with these spruces while the water-based stain gave poor results.



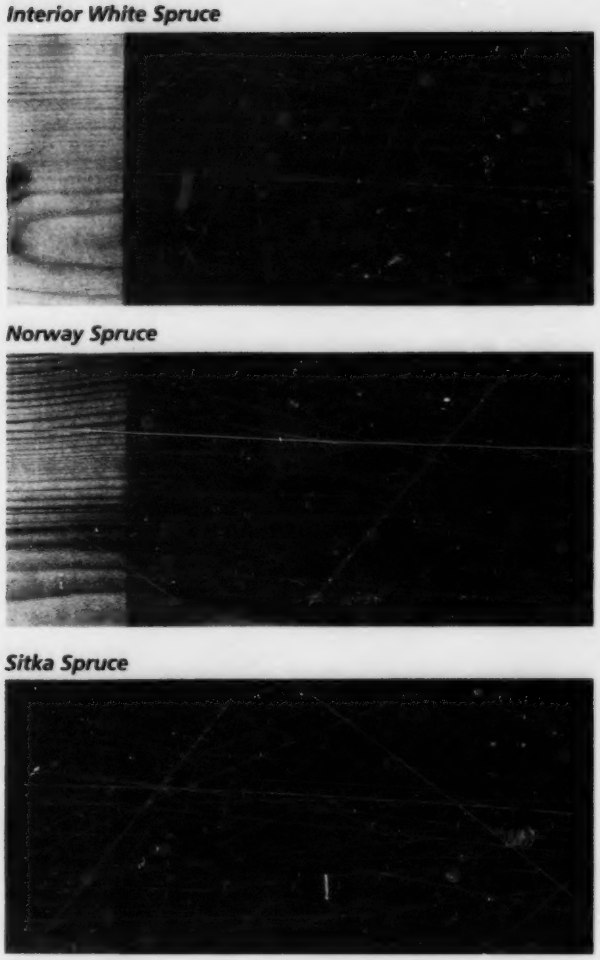


Figure 14
Comparison of Imported versus Domestic Spruce with Light Oak Penetrating Stain

Broadleaf Maple, Western White Birch and Red Alder

With each of these hardwood species the lighter stains worked the best (Figure 15). By comparison, the darker stains had results that were more varied. The maple was clearly superior, outperforming both the birch and alder.

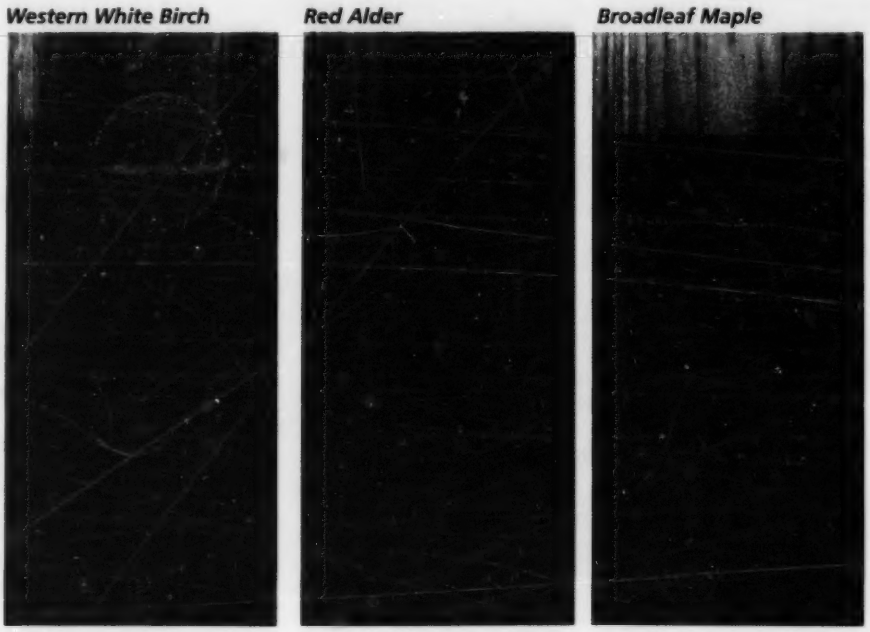


Figure 15
Comparison of Hardwoods with Light Oak Penetrating Stain

Wax Finishes

Wax coating is a very old method of applying a finish to a wood surface that has fallen out of favour in recent years. It is used more extensively in Europe than in North America. Its level of use in Europe can in part be attributed to its low impact on the environment with relatively low emissions of VOCs (volatile organic compounds). The wax coating test is a straight forward application of a wax finish onto a finely sanded wood surface. In this study, a hard wax coating was applied in three colours and the finish evaluation was based on smoothness and colour uniformity after the wax coating had been burnished (buffing the wax coating to a shine).

As in the case of the furniture finish tests there are no test protocols to evaluate wax finishes. Compared to a typical furniture finish a wax finish does not offer the same protection to the wood; in fact it offers the least amount of protection of any coating. Regardless of these disadvantages it does have its uses in interior applications. The authors learned that wax finishes are used extensively in Europe, where they are said to have a 25% market share of all finishes used for interior applications such as furniture, cabinet doors and interior passage doors. Wax finishes do offer the benefit of being the simplest to apply and require little in the way of an expensive finishing line. A hard wax finish is very similar to waxes used for car polish but with a difference in that there is colour in the wax.

Equipment

Waxes are applied using a number of techniques such as with a rag, brush, or finely woven steel wool of the 0000 grade. The hard wax coatings were applied using the steel wool. A power buffer with fine Scotch-Brite™ pads was used to burnish the surfaces.

Procedure

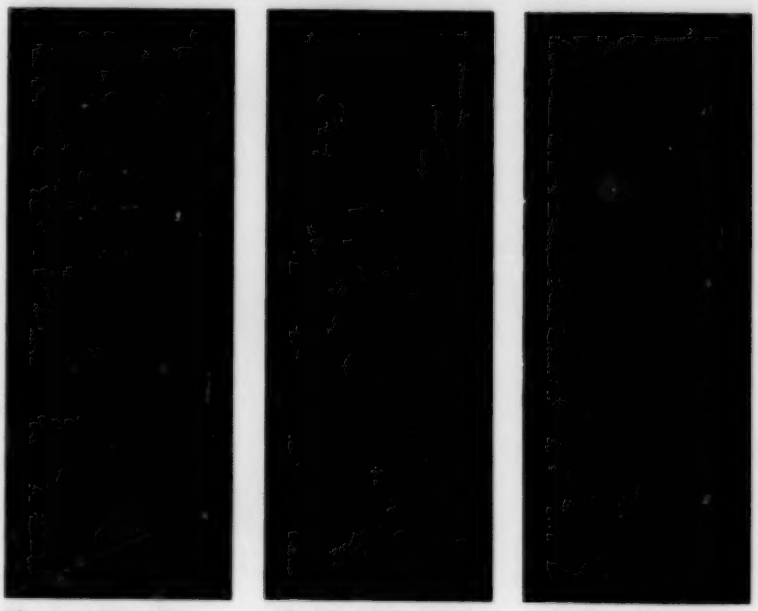
Prior to the wax coatings being applied, each of the sample pieces were sanded progressively with 150 grit paper to a final sanding with 400 grit paper. Samples pieces were tested using three hard wax finishes including Jacobean, Chestnut and Mellow Pine. Two coats were applied with approximately one hour between coats. The final coat was burnished using a fine grade of Scotch-Brite™ pad mounted onto a power sanding machine, followed by final polishing with a clean rag.

Table 4 Hard Wax Finishing Test Results

Species	Colour Uniformity		
	Mellow Pine	Chestnut	Jacobean

Note: Overall Ranking – 1 excellent, 2 good and 3 fair

Figure 16 *Selected Wax Finish/Species Combinations*



Chestnut Pine Wax Finish on Douglas-fir

Chestnut Wax Finish on White Pine

Mellow Pine Wax Finish on White Birch

Wax Finishes

Wax coating is a very old method of applying a finish to a wood surface that has fallen out of favour in recent years. It is used more extensively in Europe than in North America. Its level of use in Europe can in part be attributed to its low impact on the environment with relatively low emissions of VOCs (volatile organic compounds). The wax coating test is a straight forward application of a wax finish onto a finely sanded wood surface. In this study, a hard wax coating was applied in three colours and the finish evaluation was based on smoothness and colour uniformity after the wax coating had been burnished (buffing the wax coating to a shine).

As in the case of the furniture finish tests there are no test protocols to evaluate wax finishes. Compared to a typical furniture finish a wax finish does not offer the same protection to the wood; in fact it offers the least amount of protection of any coating. Regardless of these disadvantages it does have its uses in interior applications. The authors learned that wax finishes are used extensively in Europe, where they are said to have a 25% market share of all finishes used for interior applications such as furniture, cabinet doors and interior passage doors. Wax finishes do offer the benefit of being the simplest to apply and require little in the way of an expensive finishing line. A hard wax finish is very similar to waxes used for car polish but with a difference in that there is colour in the wax.

Equipment

Waxes are applied using a number of techniques such as with a rag, brush, or finely woven steel wool of the 0000 grade. The hard wax coatings were applied using the steel wool. A power buffer with fine Scotch-Brite™ pads was used to burnish the surfaces.

Procedure

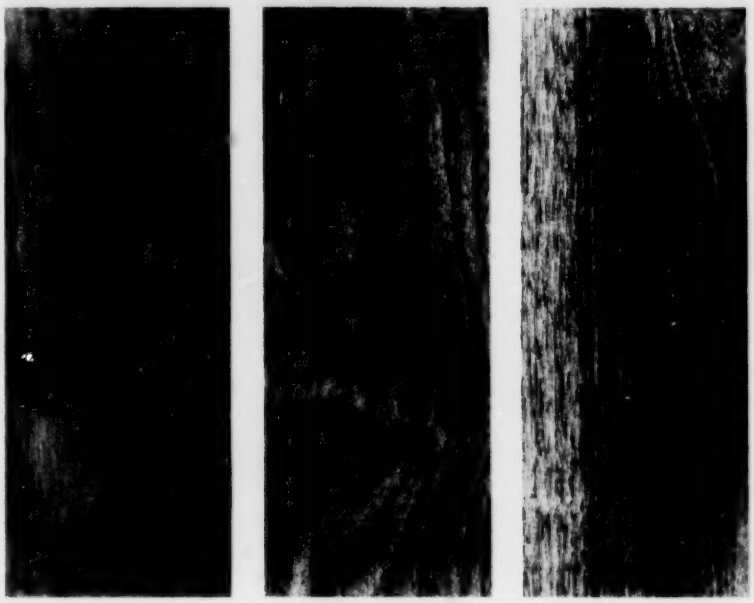
Prior to the wax coatings being applied, each of the sample pieces were sanded progressively with 150 grit paper to a final sanding with 400 grit paper. Samples pieces were tested using three hard wax finishes including Jacobean, Chestnut and Mellow Pine. Two coats were applied with approximately one hour between coats. The final coat was burnished using a fine grade of Scotch-Brite™ pad mounted onto a power sanding machine, followed by final polishing with a clean rag.

Table 4 Hard Wax Finishing Test Results

Species	*Colour Uniformity*		
	Mellow Pine	*Chestnut*	*Jacobean*
Western white pine	1	2	3
Yellow cedar	1	1	3
Western hemlock - second growth	1	1	2
Western hemlock - old-growth	1	2	3
Amabilis fir-old-growth	1	1	2
Western redcedar - coastal	3	1	1
Trembling aspen	1	3	3
Lodgepole pine	1	2	3
Interior white spruce	1	2	3
Broadleaf maple	1	3	3
Red alder	1	1	1
Western larch	1	1	2
Douglas-fir - second growth	1	1	3
Douglas-fir - old-growth	1	1	3
Sitka spruce	1	2	3
White birch	1	1	2
Subalpine fir	1	2	3
Western redcedar-interior	1	2	1

Note: Overall Ranking - 1 excellent, 2 good and 3 fair

Figure 16 *Selected Wax Finish/Species Combinations*



Chestnut Pine Wax Finish on Douglas-fir

Chestnut Wax Finish on White Pine

Mellow Pine Wax Finish on White Birch

Wax Finish Results

Table 4 shows the results of the wax finishing test. The wax coatings were evaluated with regard to smoothness and colour uniformity. Overall, the hard wax finish produced an ultra-smooth finish with a deep shine, often giving the wood an attractive "antique" type appearance (Figure 16). Care had to be taken in its application so as not to allow it to dry out, otherwise the burnishing (polishing) operation was more time consuming. Mellow pine, being a light coloured wax coating, produced the best results overall. This was also the case with other light finishes used on softwoods. The Chestnut wax coating, being medium in colour, did not have a good appearance on the pine species. The Jacobean wax finish, having the darkest colour, only did well with the western redcedars and red alder.

Finish Adhesion

The adhesion tests investigated how well standard industrial types of coatings, most of which are paints, adhered to the different wood species. The coatings selected represent a broad range of commercially available paints and stains. Adhesion of a coating to a wood substrate is influenced to a great extent by its ability to wet the wood substrate surface. Evidence of poor wetting can be found in the adhesion data and flaws in the surface appearance such as craters and pinholes. Another factor that can influence adhesion is the surface preparation of the wood substrate. Preparation of the test samples consisted of machine sanding with 150-grit sandpaper. All coatings were applied according to the manufacturers' instructions using conventional air spray system. Two coats of each finish were applied to each wood species.

The finishes were:

interior varnish (#1)
interior alkyd primer/enamel top coat (#2)
interior lacquer primer/lacquer top coat (#3)
exterior semi-transparent stain (#4)
exterior solid color acrylic stain (#5)
exterior clear finish (#6)

Following application of these finishes, two ASTM test procedures were used to measure the adhesion: D 3359 *Test Method for Measuring Adhesion by Tape Tests* and D 4541 *Test Method for Pull-Off Strength of Coatings Using Portable Adhesion-Tester*. Each coating was applied to one sample from each species.

Test Methods

The adhesion tests provide quantitative data on the suitability of using each of the different wood species as a substrate for most common painting systems. The first test, D 3359, involves the use of tape that is bonded to a specially scored painted surface. The tape is then pulled off and the resulting surface is examined to see if the coating material has been removed from either the substrate or the underlying coat. The percentage of the hatched area that remains on the tape is evaluated visually under a light source.

The second test, D 4541, involves the determination of the force required to pull off a round plug from the painted surface. A standard tensile testing machine is used to measure the force. The plug is bonded to the painted surface with high strength epoxy glue. A tensile force is applied until failure occurs.

Equipment

The tape test used a multi-blade cutter to score a hatch pattern into a painted surface. The tape used was a one-inch-wide semi-transparent pressure-sensitive tape available from a specialty supplier of quality tape.

The equipment used in the pull-off test was an improvement over the ASTM recommended portable adhesion tester. Instead, an Instron 4202 universal-testing machine with a 10kN load cell was used. With this testing machine, the load can be applied in a controlled manner whereas with the portable adhesion tester the rate of applying a load varies because it is done manually. Two jigs had to be fabricated to hold the specially designed dollies (plugs) so that this machine could be used.

Procedure

For the tape test, a multi-blade cutter was used to score lines 1 mm apart and 20 mm long through to the wood substrate and this was repeated at 90° to the first set of score lines to form a lattice pattern (Figure 17). The surface was cleaned of any small fragments. The first two complete laps of tape were discarded then a length of tape was cut that covered the hatched marks. To ensure good contact, the tape was rubbed with the eraser end of a pencil. Within 90 seconds after application, the tape was rapidly pulled back upon itself at as close to a 180 ° angle as possible (Figure 18).

The grid area was then inspected for removal of coating from the substrate. The classification system used to rate the adhesion can be found in Table 5.

The tape test was performed once for each of the samples.

For the pull-off test, a steel metal plug was glued to the coated wood surface using the recommended epoxy adhesive (Araldite 2011 High Strength Epoxy Adhesive) and allowed to cure. Constant pressure was applied to the plug during the setting and curing of the adhesive. A total of eight pull-off tests were performed on each sample with plugs being spaced at least 5 cm apart and no closer than 2 cm from the edge and 4 cm from the ends. Only one plug was glued to a sample at any one time.

The two-jig arrangement permitted the plug to be centred accurately over the central axis of the tester thereby limiting the chance of the plug being peeled off. Figure 19 shows the pull-off test set-up. The tester was programmed to produce an extension rate of 2.8 mm/minute. This rate was arrived at after numerous trials. The force exerted at failure was automatically recorded. An adhesion strength value (kg/cm^2) was calculated using the contact surface area of the 20 mm diameter plug and the peak load (kg) for each test result. Figure 20 shows the result of a pull-off test.

Adhesion Test Results

Tables 6 and 7 showed the results for the tape test and pull-off test respectively. The tape test results show that no adhesion problems existed amongst any of the species tested. With regard to the average values for each species (down the right side of Table 6), it can be seen that most are equally divided between four to five which means that there was less than five per cent of the area exhibiting flaking of the coating. Looking at the average values for each type of coating (across the bottom of Table 6) it can be seen that Finish #3, the interior lacquer primer with a lacquer topcoat, produced the lowest overall average with six instances of values as low as 2. This finish, with its lacquer content, is hard and brittle which most likely accounted for the proportionally larger area of flaking. Finish #2, the interior alkyd primer with an enamel topcoat, also produced some low values for some of the wood species. The enamel, also being hard, made the surface somewhat brittle though not as much as the lacquer system.

The pull-off test results shown in Table 7 confirmed that the wood species tested did not

Figure 17
Scoring for Tape Test

Figure 18
Tape Pull-off Test

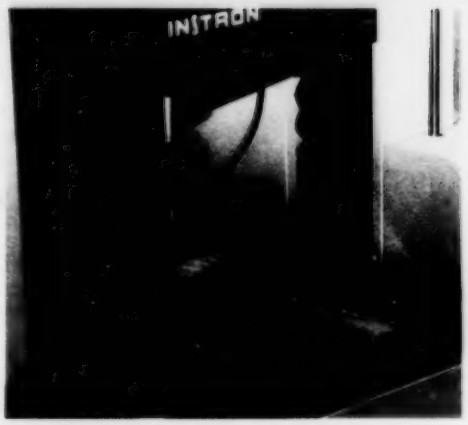


Figure 19
Pull-off Test Set-up

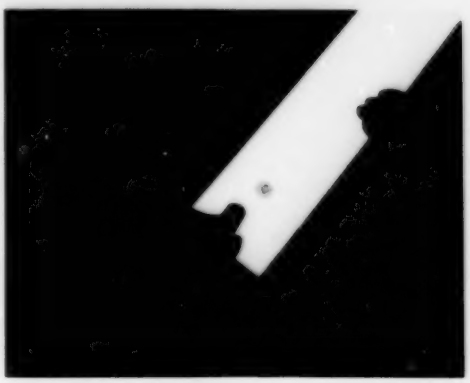


Figure 20
Plug for Pull-off Test

M121

IMPORTANT NOTE CONCERNING THE FOLLOWING PAGES

THE PAGES WHICH FOLLOW HAVE BEEN FILMED TWICE IN ORDER TO OBTAIN THE BEST REPRODUCTIVE QUALITY

USERS SHOULD CONSULT ALL THE PAGES REPRODUCED ON THE FICHE IN ORDER TO OBTAIN A COMPLETE READING OF THE TEXT.

REMARQUE IMPORTANTE CONCERNANT LES PAGES QUI SUIVENT

LES PAGES SUIVANTES ONT ÉTÉ REPRODUITES EN DOUBLE AFIN D'AMÉLIORER LA QUALITÉ DE REPRODUCTION

LES UTILISATEURS DOIVENT CONSULTER TOUTES LES PAGES REPRODUITES SUR LA FICHE AFIN D'OBTENIR LA LECTURE DU TEXTE INTÉGRAL

micromedia
a division of IHS Canada

20 Victoria Street
Toronto, Ontario M5C 2N8
Tel.: (416) 362-5211
Toll Free: 1-800-387-2689
Fax: (416) 362-6161
Email: info@micromedia.on.ca

exhibit any problems with adhesion when a variety of commercially available wood coatings are applied properly. In the opinion of a finishing expert, any force greater than 7 kg/cm^2 (100psi) for wood is considered to be sufficient. A number of species had a pull-off force at least four to five times greater than what is considered adequate with the remaining species having pull off forces from two to three times greater. One of the lowest averages was turned in by southern yellow pine. With this species the values were consistently low across a range of coatings. Radiata pine also had results that were lower than average. The Douglas-fir samples showed some surprising results, with the interior Douglas-fir variant producing some impressive values and the second-growth variant showing quite respectable results. All the western hemlock results were very consistent which indicated that there

Table 5 Tape Test Grading Categories

Category	*Description*
5	Edges of the cuts were completely smooth; none of the squares of the lattice was detached.
4	Small flakes of the coating were detached at intersections; less than 5% of the area affected.
3	Small flakes of the coating were detached along edges and at intersections of cuts; the area affected was 5 to 15% of the lattice.
2	The coating flaked along the edges and on parts of the squares; the area affected is 15 to 35% of the lattice.
1	The coating flaked along the edges of cuts in large ribbons and whole squares have detached; the area affected was 35 to 65% of the lattice.
0	Flaking and detachment over 65%

Table 6 Tape Test Results

Species	*Tape Adhesion Test*						*Average*
	Interior Coatings			*Exterior Coatings*			
	#1	*#2*	*#3*	*#4*	*#5*	*#6*	
Western white pine	5	4	3	5	5	4	4
Yellow cedar	5	5	3	5	5	5	5
Western hemlock - second-growth	5	4	3	4	5	5	4
Western hemlock - old-growth	5	4	3	4	5	4	4
Amabilis fir	5	4	4	4	4	4	4
Western redcedar	5	3	2	4	5	5	4
Trembling aspen	5	3	3	5	4	4	4
Lodgepole pine	5	3	3	4	5	5	4
Interior white spruce	5	4	3	4	4	5	4
Broadleaf maple	5	4	4	5	5	5	5
Red alder	5	4	4	5	5	4	5
Western larch	5	5	3	4	5	5	5
Douglas-fir - second-growth	5	4	5	5	5	5	5
Douglas-fir - old-growth	5	4	2	4	5	4	4
Sitka spruce	5	5	2	5	5	5	5
White birch	5	5	3	5	5	5	5
Subalpine fir	5	4	3	3	4	5	4
Western redcedar - interior	5	4	2	4	4	5	4
Ponderosa pine	5	5	4	4	5	4	5
Norway spruce	5	3	2	5	4	5	4
Radiata pine	5	3	2	5	5	4	4
Southern yellow pine	5	4	3	4	5	4	4
Average	5	4	3	4	5	5	4

Key to Coating #'s: interior varnish (#1), interior alkyd primer/enamel top coat (#2), interior lacquer primer/lacquer top coat (#3), exterior semi-transparent stain (#4), exterior solid color acrylic stain (#5), exterior clear finish (#6).

was no difference in coating adhesion between old-growth and second-growth fibre. One other surprise was that trembling aspen had one of the highest average pull-off test results. This indicated that it absorbs various types of coatings well.

The average for the coatings, seen across the bottom of the table, shows that the lowest values were experienced with finish #3. This correlated well with the outcomes of the tape test regarding these two coatings. It must be noted however, that not all the species had lower than average values for these two coatings. The three cedars tested had results that were on par with the results produced with the other coatings.

Table 7 Pull-Off Test Results

Species	Average Strength per Sample (kg/cm²)						Average Strength (kg/cm²)
	Interior Coatings			Exterior Coatings			
	#1	#2	#3	#4	#5	#6	
Western white pine	30	26	14	40	37	34	30
Yellow cedar	26	23	27	46	53	21	33
Western hemlock - second growth	34	25	27	41	48	9	31
Western hemlock - old-growth	29	31	19	34	40	25	30
Amabilis fir	24	39	20	24	29	24	27
Western redcedar - coastal	17	23	17	33	44	24	26
Trembling aspen	64	42	14	43	43	38	41
Lodgepole pine	46	19	13	34	41	26	30
Interior white spruce	34	23	19	35	44	34	31
Broadleaf maple	37	27	21	42	49	34	35
Red alder	44	26	26	26	55	11	31
Western larch	31	35	23	46	54	16	29
Douglas-fir - second growth	36	25	10	25	37	40	32
Douglas-fir - old-growth	38	31	9	24	48	12	27
Sitka spruce	29	17	9	31	42	31	26
White birch	24	17	20	19	59	37	29
Subalpine fir	28	32	20	32	36	29	29
Western redcedar - interior	18	19	22	30	34	18	23
Ponderosa pine	40	35	23	38	45	13	32
Norway spruce	25	37	21	40	36	28	31
Radiata pine	21	15	23	18	24	28	22
Southern yellow pine	19	18	16	34	23	14	21
Average Strength (kg/cm²)	33	25	18	34	43	25	

Key to Coating #'s: interior varnish (#1), interior alkyd primer/enamel top coat (#2), interior lacquer primer/lacquer top coat (#3), exterior semi-transparent stain (#4), exterior solid color acrylic stain (#5), exterior clear finish (#6).

exhibit any problems with adhesion when a variety of commercially available wood coatings are applied properly. In the opinion of a finishing expert, any force greater than 7 kg/cm² (100psi) for wood is considered to be sufficient. A number of species had a pull-off force at least four to five times greater than what is considered adequate with the remaining species having pull off forces from two to three times greater. One of the lowest averages was turned in by southern yellow pine. With this species the values were consistently low across a range of coatings. Radiata pine also had results that were lower than average. The Douglas-fir samples showed some surprising results, with the interior Douglas-fir variant producing some impressive values and the second-growth variant showing quite respectable results. All the western hemlock results were very consistent which indicated that there

Table 5 Tape Test Grading Categories

Category	*Description*
5	Edges of the cuts were completely smooth; none of the squares of the lattice was detached.
4	Small flakes of the coating were detached at intersections; less than 5% of the area affected.
3	Small flakes of the coating were detached along edges and at intersections of cuts; the area affected was 5 to 15% of the lattice.
2	The coating flaked along the edges and on parts of the squares; the area affected is 15 to 35% of the lattice.
1	The coating flaked along the edges of cuts in large ribbons and whole squares have detached; the area affected was 35 to 65% of the lattice.
0	Flaking and detachment over 65%

Table 6 Tape Test Results

Species	*Tape Adhesion Test*						*Average*
	Interior Coatings			*Exterior Coatings*			
	#1	*#2*	*#3*	*#4*	*#5*	*#6*	
Western white pine	5	4	3	5	5	4	4
Yellow cedar	5	5	3	5	5	5	5
Western hemlock - second-growth	5	4	3	4	5	5	4
Western hemlock - old-growth	5	4	3	4	5	4	4
Amabilis fir	5	4	4	4	4	4	4
Western redcedar	5	3	2	4	5	5	4
Trembling aspen	5	3	3	5	4	4	4
Lodgepole pine	5	3	3	4	5	5	4
Interior white spruce	5	4	3	4	4	5	4
Broadleaf maple	5	4	4	5	5	5	5
Red alder	5	4	4	5	5	4	5
Western larch	5	5	3	4	5	5	5
Douglas-fir - second-growth	5	4	5	5	5	5	5
Douglas-fir - old-growth	5	4	2	4	5	4	4
Sitka spruce	5	5	2	5	5	5	5
White birch	5	5	3	5	5	5	5
Subalpine fir	5	4	3	3	4	5	4
Western redcedar - interior	5	4	2	4	4	5	4
Ponderosa pine	5	5	4	4	5	4	5
Norway spruce	5	3	2	5	4	5	4
Radiata pine	5	3	2	5	5	4	4
Southern yellow pine	5	4	3	4	5	4	4
Average	5	4	3	4	5	5	4

Key to Coating #'s: interior varnish (#1), interior alkyd primer/enamel top coat (#2), interior lacquer primer/lacquer top coat (#3), exterior semi-transparent stain (#4), exterior solid color acrylic stain (#5), exterior clear finish (#6).

was no difference in coating adhesion between old-growth and second-growth fibre. One other surprise was that trembling aspen had one of the highest average pull-off test results. This indicated that it absorbs various types of coatings well.

The average for the coatings, seen across the bottom of the table, shows that the lowest values were experienced with finish #3. This correlated well with the outcomes of the tape test regarding these two coatings. It must be noted however, that not all the species had lower than average values for these two coatings. The three cedars tested had results that were on par with the results produced with the other coatings.

Table 7 Pull-Off Test Results

Species	Average Strength per Sample (kg/cm²)						Average Strength (kg/cm²)
	Interior Coatings			Exterior Coatings			
	#1	#2	#3	#4	#5	#6	
Western white pine	30	26	14	40	37	34	30
Yellow cedar	26	23	27	46	53	21	33
Western hemlock - second growth	34	25	27	41	48	9	31
Western hemlock - old-growth	29	31	19	34	40	25	30
Amabilis fir	24	39	20	24	29	24	27
Western redcedar - coastal	17	23	17	33	44	24	26
Trembling aspen	64	42	14	43	43	38	41
Lodgepole pine	46	19	13	34	41	26	30
Interior white spruce	34	23	19	35	44	34	31
Broadleaf maple	37	27	21	42	49	34	35
Red alder	44	26	26	26	55	11	31
Western larch	31	35	23	46	54	16	29
Douglas-fir - second growth	56	25	10	25	37	40	32
Douglas-fir - old-growth	38	31	9	24	48	12	27
Sitka spruce	29	17	9	31	42	31	26
White birch	24	17	20	19	59	37	29
Subalpine fir	28	32	20	32	36	29	29
Western redcedar - interior	18	19	22	30	34	18	23
Ponderosa pine	40	35	23	38	45	13	32
Norway spruce	25	37	21	40	36	28	31
Radiata pine	21	15	23	18	24	28	22
Southern yellow pine	19	18	16	34	23	14	21
Average Strength (kg/cm²)	33	25	18	34	43	25	

Key to Coating #'s: interior varnish (#1), interior alkyd primer/enamel top coat (#2), interior lacquer primer/lacquer top coat (#3), exterior semi-transparent stain (#4), exterior solid color acrylic stain (#5), exterior clear finish (#6).

Conclusions

Finish Appearance

- Light stains work best with the softwood species.
- Darker stains tend to produce an uneven and blotchy appearance when applied to softwoods.
- Water-borne stain did not work well with either the softwoods or the hardwoods tested.
- Water-borne topcoats provided good results when applied over solvent-based sealers.
- BC pines finish just as well as, or better, in some instances than imported pines from the U.S. and Chile.
- Second-growth fibre finishes better than old-growth fibre and tends to be more visually appealing.
- Western hemlock and amabilis fir should not be used in the same finished wood product.
- SPF species can be used interchangeably in the same finished wood products as can Douglas-fir and western larch species.
- Interior western redcedar is an attractive wood species when finished with a number of furniture-type finishes.
- The oil stain worked best with nearly all the species although it took much longer to dry.
- Wax finishes offer a more environmentally friendly (low VOCs) alternative to more conventional North American finishing systems and produce a high-quality finish on most BC species.

Adhesion Testing

- None of the wood species tested exhibited adhesion problems when a broad range of commercially available coatings were applied.

Recommendations

- Species that had problems with blotchiness caused by uneven stain penetration should have further finishing tests performed using a pre-stain treatment to reduce stain absorption.
- Western hemlock and amabilis fir should be sorted if they are going to be used in finished wood products of high value where finish appearance is important.
- The superior finishing properties of second growth western hemlock and Douglas-fir over their respective old-growth variants needs to be communicated to industry and other stakeholders.

References

[1]American Society for Testing and Materials. 1994. ASTM D 3359-93: *Standard Test Methods for Measuring Adhesion by Tape Test. Annual Book of ASTM Standards*. Philadelphia, PA: ASTM. Vol. 06.01. p.432.

[2]American Society for Testing and Materials. 1994. ASTM D 4541-93: *Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Tester. Annual Book of ASTM Standards*. Philadelphia, PA: ASTM. Vol. 06.02. p.344.